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(19) (CA) **CANADIAN PATENT** (12)

(54) Pneumatic Radial Tire Having a Good High-Speed
　　　Running Performance

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Canada

This invention relates to a pneumatic tire having a good high-speed running performance, and more particularly to a pneumatic radial tire for passenger cars having an improved steering response during

05 a high-speed running.

In general, tire tread rubbers are required to have characteristics such as wet resistance, cut resistance, slip resistance and the like, and also substantially affect a rolling resistance which is

10 closely related to a fuel consumption of an automobile vehicle. Among these characteristics, the slip resistance (wet skid resistance, etc) particularly tends to be conflictive to the rolling resistance, so that the use of a rubber advantageous for the former

15 becomes disadvantageous for latter, and to the contrary, the use of a rubber advantageous for the latter becomes disadvantageous for the former. In order to improve such conflicting characteristics simultaneously, there have been known tread rubbers having such a composite

20 structure that a rubber having an excellent wear resistance is definitely used in a portion particulary exposed to wearing during the running and a rubber suitable for the rolling resistance is used in the other portions.

25 With respect to the composite structure of the tread rubber, in addition to the above, as described in, for example, United States Patent Specification No. 3,759,306 there is proposed a structure that a rubber

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having a considerably high stretch modulus is used
in a base portion bounded by bottoms of tread grooves
for preventing the wrenching out of tread ribs from
their root during the running of passenger tire at
05   a high speed and a rubber having an excellent wear
resistance and a relative low stretch modulus is usually
used in portions exposed to wearing.

The invention is different from the above
mentioned prior composite structure, and is to largely
10   improve the steering response at high-speed of radial
tires by composing a particular composite tread struc-
ture consisting of an inner layer having a properly
high modulus of elasticity in portions forming the base
such as rib, block, lug or the like cast into the tread
15   portion, and an outer layer arranged on the inner layer
and having a particularly improved gripping property on
road surface and a modulus of elasticity controlled in
a given ratio with respect to the inner layer.

According to the invention, there is the
20   provision of in a pneumatic radial tire having a good
high-speed running performance, comprising a tread
portion, a pair of sidewall portions toroidally
extending from the both sides of the tread portion,
a carcass reinforcing these portions and composed of at
25   least one ply containing cords arranged in a direction
perpendicular to the equational plane of the tire, and
a belt disposed between the carcass and the tread
portion and composed of plural inextensible cord layers,

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the improvement wherein said tread portion is divided
into at least two composite rubber layers in a direction
of the thickness, in which an inner rubber layer near
to the belt has a dynamic modulus (E') of 100-250 kg/cm^2

05 and an outer rubber layer has a dynamic modulus (E') of
70-150 kg/cm^2 and a loss tangent (tan δ) of at least
0.25, and a ratio in dynamic modulus (E') of the inner
rubber layer to the outer rubber layer is at least 1.15.

The invention is particularly useful for

10 application to tires having an aspect ratio of not more
than 70%, preferably 60%, more preferably 50%.

A single figure is a right half cross-sectional
view of an embodiment of the pneumatic radial tire
according to the invention.

15 In the single figure is shown a radial
right-half section of the pneumatic radial tire according
to the invention. In the tire 1, a pair of right and
left sidewall portions 2 are toroidally connected to
both sides of a tread portion 3. Although the left-half

20 section is omitted, tire 1 is, of course, symmetrical
with respect to an equational plane O-O.

A bead ring 4 is embedded in an inwardly and
part of each of the sidewall portions 2 in the radial
direction in the conventional manner, and a carcass 5

25 is extended between both the bead rings 4 to wholly
reinforce the sidewall and tread portions.

The carcass 5 is composed of one ply or
plural plies, each ply containing cords of an organic

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fiber such as polyester fiber, nylon fiber, rayon fiber or the like arranged in a direction substantially perpendicular to the equational plane O-O. In the illustrated embodiment, the carcass 5 is one ply, both end portions of which are wound outwardly around the bead rings 4 to form turnup portions 6, respectively. Further, a hard rubber filler 7 is disposed in a space defined by the carcass 5, turnup portion 6 and bead ring 4 and tapered toward the direction of the tread portion.

As the rubber filler 7, it is better to use rubber having a dynamic modulus of 600-1,500 kg/cm^2.

Since a so-called radial structure as mentioned above is used as the carcass 5, a belt 8 composed of inextensible cord layers is disposed between the carcass 5 and the tread portion 3 in the usual manner, whereby the rigidity of the tread portion is enhanced as a whole.

The reinforcing element for the belt 8 is a metal cord such as steel and the like or a high elastic fiber cord such as glass, polyester, rayon, aromatic polyamide and the like. These cords may be used alone or particularly in combination of metal cord with fiber cord. The belt 8 is composed of plural cord layers each containing such cords arranged at an inclination angle of 5°-25° with respect to the equational plane O-O, the cords of which being crossed with each other.

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Although the belt 8 is constructed by merely
laminating two steel cord layers 8-1 and 8-2 one upon
the other in the illustrated embodiment, there may
be a so-called fold belt structure wherein the cord
05 layer 8-1 is made wider and both side ends thereof are
folded and piled on the cord layer 8-2, or a structure
that one layer or at most two layers containing heat
shrinkable fiber cords such as nylon cord arranged in
parallel to or at a slight inclination angle with
10 respect to the equational plane O-O may directly be
disposed on the belt shown in the figure to partially
or wholly cover it therewith.

The tread portion 3 is composed of a composite
rubber layer comprising an outer rubber layer 9 directly
15 contacted fitted with road surface during the running
and an inner rubber layer 10 supporting the outer
rubber layer 9 on the belt 8.

The outer rubber layer 9 has a loss tangent
(tan δ) of at least 0.25 and a dynamic modulus (E') of
20 70-150 kg/cm^2. While, the inner rubber layer 10 has
a dynamic modulus (E') of 100-250 kg/cm^2. Then, a ratio
of the inner rubber layer 10 to the outer rubber layer
9 in dynamic modulus (E') is required to be at least 1.15.

According to the invention, the outer rubber
25 layer 9 is a rubber having an improved gripping property
against road surface in addition to wear resistance,
and it has been confirmed from the experiments by the
inventors that when the ratio in dynamic modulus between

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the outer rubber layer 9 and the inner rubber layer 10
is within the above defined range, the gripping property
is more enhanced together with a suitable flexibility
effect of tread rubber (actually rib, block, lug or the

05 like) at the ground contact area in the steering during
the running.   In this case, the outer rubber layer 9
has a loss tangent (tan δ) of at least 0.25, preferably
of 0.3-0.5 and a dynamic modulus of 70-150 kg/cm^2,
preferably of 80-140 kg/cm^2, and the inner rubber layer

10 10 has a dynamic modulus (E') of 100-250 kg/cm^2,
preferably of 110-200 kg/cm^2.   Further, the ratio in
dynamic modulus of inner rubber layer 10 to outer
rubber layer 9 is at least 1.15, preferably 1.25-2.0.
Moreover, as to a ratio of thickness between the inner

15 rubber layer 10 and the outer rubber layer 9, good
results are obtained when an average thickness of the
inner rubber layer 10 is within a range of 0.15-0.35
relative to 1 of that of the outer rubber layer 9.
The reason why the thickness of each rubber layer is

20 expressed on average is due to the fact that when the
tread portion 3 is composed of, for example, ribs 14
divided by a large number of grooves 13, the joint
surface between the inner and outer rubber layers 10, 9
becomes wavy as shown in the figure.

25 　　　　Though the composite rubber layer composed of
two inner and outer layers is shown in the illustrated
embodiment, a third or fourth rubber layer may be added
as far as the object is maintained.

As shown in this embodiment, it is preferable that the outer rubber layer 9 and the inner rubber layer 10 are substantially piled one upon the other over the whole of the tread portion, and both side end

05 portions thereof are extend in wedge form into rubbers 12 of the sidewall portions having a good flexing property at positions of tire shoulders 11. Moreover, numeral 15 is an inner liner having an excellent air impermeability.

10   In order to confirm the performances of the tire according to the invention, the actual running test was carried out on a circuit course (2.04 km) by using a test tire with a size of 205/60R 15, during which a lap time was actually measured and also the

15 steering response, stability, wet skid resistance and riding comfort in the high-speed running and in the running on usual road were estimated by feeling.

      Moreover, the feeling in the running on the circuit is based on a total evaluation of driving and

20 braking properties, steering response, gripping property against road surface during the steering and controllability beyond slip limit.

      As a test tire were used tires A, B and C according to the invention and control tire D.

25   All of these tires had a common feature that two rubberized plies each containing polyester cords arranged in a direction perpendicular to the equational plane O-O of the tire were wound around the bead ring 4

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from inside to outside as shown in the figure, and the bead filler rubber 7 having a considerably high dynamic modulus was interposed between the carcass ply and its turnup portion. Moreover, as the belt 8, two layers 8-1 and 8-2 each containing metal cords arranged at an inclination angle of 20° with respect to the equational plane O-O were laminated so as to cross the cords of these layers with each other as shown in the figure, and two reinforcing layers each containing nylon cords arranged at an angle of 0° with respect to the equatorial plane O-O (not shown) were arranged on each side end portion of the layer 8-2 to particularly reinforce both the side end portions of the belt 8.

The structure and compounding recipe of the tread rubber in each test tire are shown in the following Tables 1 and 2, respectively.

Table 1

Kinds of tire	A	B	C	D
Tread rubber ($\dfrac{\text{Outer rubber layer 9}}{\text{Inner rubber layer 10}}$)	$\dfrac{W}{Z}$	$\dfrac{X}{Z}$	$\dfrac{Y}{Z}$	Only W
Average thickness of rubber (mm) ($\dfrac{\text{Outer rubber layer 9}}{\text{Inner rubber layer 10}}$)	$\dfrac{8.0}{2.0}$	$\dfrac{8.0}{2.0}$	$\dfrac{8.0}{2.0}$	10.0

Table 2

Kind of rubber	W	X	Y	Z
Butadiene-styrene copolymer rubber (Styrene 23.5%)	50	-	-	100
Butadiene-styrene copolymer rubber (Styrene 35%)	50	100	100	-
Carbon black (HAF)	80	85	-	90
Carbon black (ISAF)	-	-	85	-
Aromatic process oil	40	45	45	35
Stearic acid	1	1	1	1
Antioxidant (IPPD)	1	1	1	1
Zinc white	3	3	3	3
Accelerator PPG / DM	0.5 / 1.0	0.5 / 1.0	0.7 / 0.8	0.6 / 1.2
Sulfur	5	1.5	1.5	1.7
Dynamic modulus (kg/cm^2)	116	97	130	173
Loss tangent	0.340	0.43	0.49	-

Note: The dynamic modulus and loss tangent were measured with respect to a strip specimen of width 5 mm×length 20 mm×thickness 2 mm using a viscoelastic spectrometer made by Iwamoto Seisakusho under the test conditions of a frequency of 50 Hz, a dynamic strain of 1% and a temperature of 25°C.

The test tire assembled onto a rim and subjected to an internal pressure of 2.2 kg/cm^2 was mounted on a vehicle and actually run to obtain results as shown in the following Table 3.

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Table 3

Kind of tire	A	B	C	D
Running lap-time (circuit)	1' 15" 81	1' 15" 10	1' 14" 70	1' 16" 25
Running feeling (circuit)	104	105	107	100
Steering response	104	105	106	100
Stability	105	105	107	100
Wet skid resistance	100	103	104	100
Riding comfort against vibration	100	100	99	100

Note: The properties other than the lap time are expressed as an index when the tire D is regarded as 100. The large the index value, the better the property.

As mentioned above, according to the invention, the steering response in the high-speed running can considerably be improved synthetically.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:-

1. In a pneumatic radial tire having a good high-speed running performance, comprising a tread portion, a pair of sidewall portions toroidally extending from the both sides of the tread portion, a carcass reinforcing these portions and composed of at least one ply containing cords arranged in a direction perpendicular to the equational plane of the tire, and a belt disposed between the carcass and the tread portion and composed of plural inextensible cord layers, the improvement wherein said tread portion is divided into at least two composite rubber layers in a direction of thickness, in which an inner rubber layer near to the belt has a dynamic modulus (E') of 100-250 kg/cm^2 and an outer rubber layer has a dynamic modulus (E') of 70-150 kg/cm^2 and a loss tangent $(\tan \delta)$ of at least 0.25, and a ratio in dynamic modulus (E') of the inner rubber layer to the outer rubber layer is at least 1.15.

2. The pneumatic radial tire according to claim 1, wherein said outer rubber layer has a dynamic modulus (E') of 80-140 kg/cm^2 and a loss tangent $(\tan \delta)$ of 0.3-0.5.

3. The pneumatic radial tire according to claim 1, wherein said inner rubber layer has a dynamic modulus (E') of 110-200 kg/cm^2.

4.   The pneumatic radial tire according to claim 1, wherein said ratio in dynamic modulus of the inner rubber layer to the outer rubber layer is within a range of 1.25-2.0.

5.   The pneumatic radial tire according to claim 1, wherein a ratio in thickness of the inner rubber layer to the outer rubber layer is within a range of 0.15-0.35 on average.

Abstract of the Disclosure

A pneumatic radial tire for passenger cars having a good high-speed running performance is disclosed, which comprises a tread portion, a pair of sidewalls portions, a carcass reinforcing these portions and composed of at least one ply containing cords arranged in a direction perpendicular to the equational plane of the tire, and a belt disposed between the carcass and the tread portion and composed of plural inextensible cord layers. In the tire of this type, the said tread portion is composed of a composite rubber divided into at least two composite rubber layers in a direction of the thickness, in which an inner rubber layer near to the belt layer has a dynamic modulus (E') of 100-250 kg/cm^2 and an outer rubber layer has a dynamic modulus (E') of 70-150 kg/cm^2 and a loss tangent (tan δ) of at least 0.25, and a ratio in dynamic modulus of the inner rubber layer to the outer rubber layer is at least 1.15.
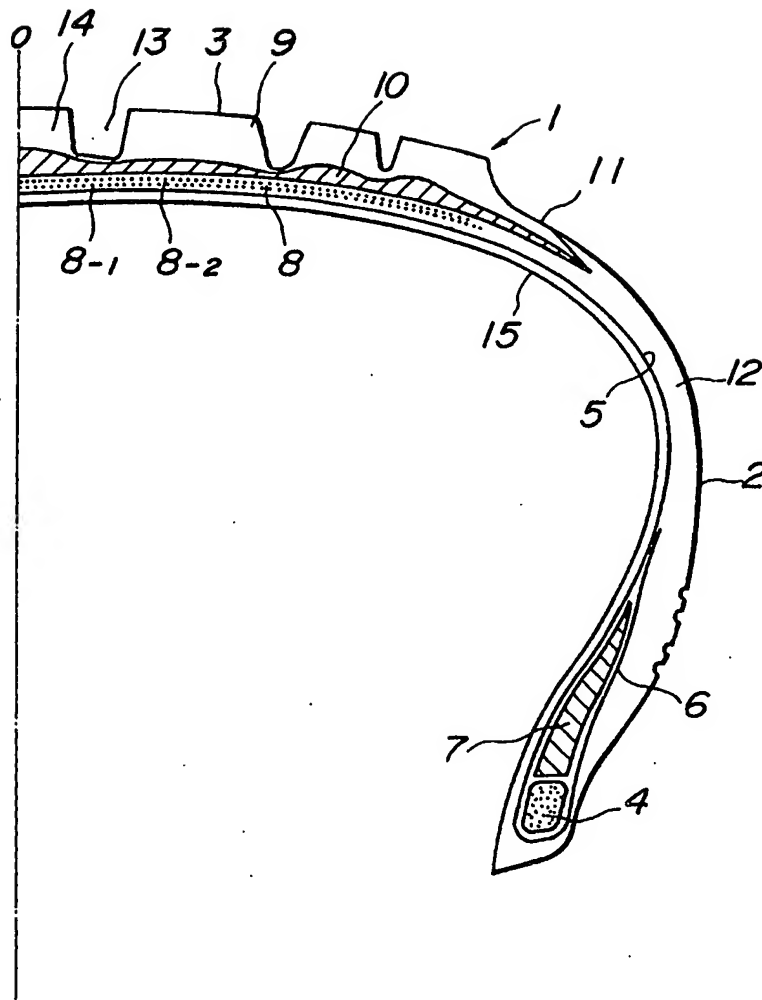
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